The Stirling Project

An advanced automotive propulsion system heads technology transfers in the field of transportation

A NASA/Department of Energy project involving development of Stirling engine technology represents an unusual kind of technology transfer. It is not an aerospace spinoff, nor is the technology even American. The Stirling engine was initially developed in The Netherlands during World War II, later improved in Sweden. Now NASA and DoE are attempting to transfer the European technology to the United States, advance it several steps and pave the way for its commercialization, because its widespread adoption could bring a number of national benefits.

The Stirling engine is a different breed of automotive propulsion system. Like standard auto engines, it burns a mixture of air and fuel to drive pistons and thus transmit power to the auto's wheels. The Stirling differs from conventional internal combustion engines in that it employs an *external* heater head, where continuous combustion takes place, located outside the cylinders.

This design concept offers many important advantages, among them lower fuel consumption, low exhaust emissions, low noise levels, minimal lubrication requirements, and potential for high reliability, long service life and reduced maintenance costs. Perhaps its most important advantage is its "multifuel capability," meaning its ability to operate on a variety of fuels, such as gasoline, kerosene, alcohol, methanol, diesel fuel, butane and others; this capability will become increasingly important with wider availability of synthetic fuels.

Since 1978, Lewis Research Center has been conducting the Automotive Stirling Engine program as project manager for DoE. The goals established at that time included improvement of at least 30 percent in fuel economy in comparison with comparable internal combustion engines in modern autos; emission levels that meet or exceed the most stringent federal requirements; multifuel capability, including both oil-derived and synthetic fuels; and development of the engine to the point where it is suitable for cost-competitive mass production. The initial base of Stirling technology was provided under subcontract by United Stirling AB, Malmö, Sweden. The American prime contractor responsible for development of engine, component and subsystem technology is Mechanical Technology, Inc. (MTI), Latham, New York.

A basic objective of the program is "to place a manufacturer and end users on the path to commercialization." A potential manufacturer is Deere & Company, Moline, Illinois. The possible end users include such fleet operators as Purolator Courier, Basking Ridge, New Jersey, which has more than 5,000 vehicles and the American Trucking Associations, Alexandria, Virginia, representing 51 associations in each state and the District of Columbia. Also participating are several government agencies. Among the latter, the major program participant is the Air Force Logistics Command's MEEP (Management and Equipment Evaluation Program) organization.

A big milestone was the September 1986 start of the program's Phase I, in which a Mod I Stirling engine is undergoing test—at Langley Air Force Base, Virginia—in a "multistop" Air Force van, a vehicle that transports people and light cargo in a stop-and-go duty cycle on the Langley flight line, providing a realistic test of the engine's capability. Throughout the planned 1,000 hours of testing, MEEP personnel are regularly evaluating the engine's fuel usage, overall performance, exhaust emissions and lubricating efficiency; they are analyzing reliability, maintenance and repair history and operational schedules, generally trying to determine whether the Stirling can in fact achieve the lower life cycle costs claimed for it.

Seven experimental Mod I engines have operated in test cells and vehicles for more than 16,000 hours. They are being used to develop and demonstrate new technologies for incorporation in a second generation Mod II engine, which is now in development. In tests thus far, the Stirling has exhibited engine performance close to predicted levels, good fuel consumption characteristics and low emissions; there has been parallel progress in advancing key technologies needed for a commercialized engine. Lewis Research Center reports that there are no technology barriers to the Stirling's eventual commercialization.

The ultimate success envisioned by the project team is mass production of Stirlings for automobile use. But before that can happen, auto manufacturers say, the Stirling engine must first be commercialized in a "starter market" application, to reduce the financial risk by providing a solid base of commercial experience and to establish a credible guideline for estimating mass production costs. Among possible starter market applications wherein the Stirling offers significant advantages are engine generators, heat pumps, irrigation pumps, trucks and power sources for submarine, solar terrestrial and space electricity generation. Development is already under way for some of these applications.

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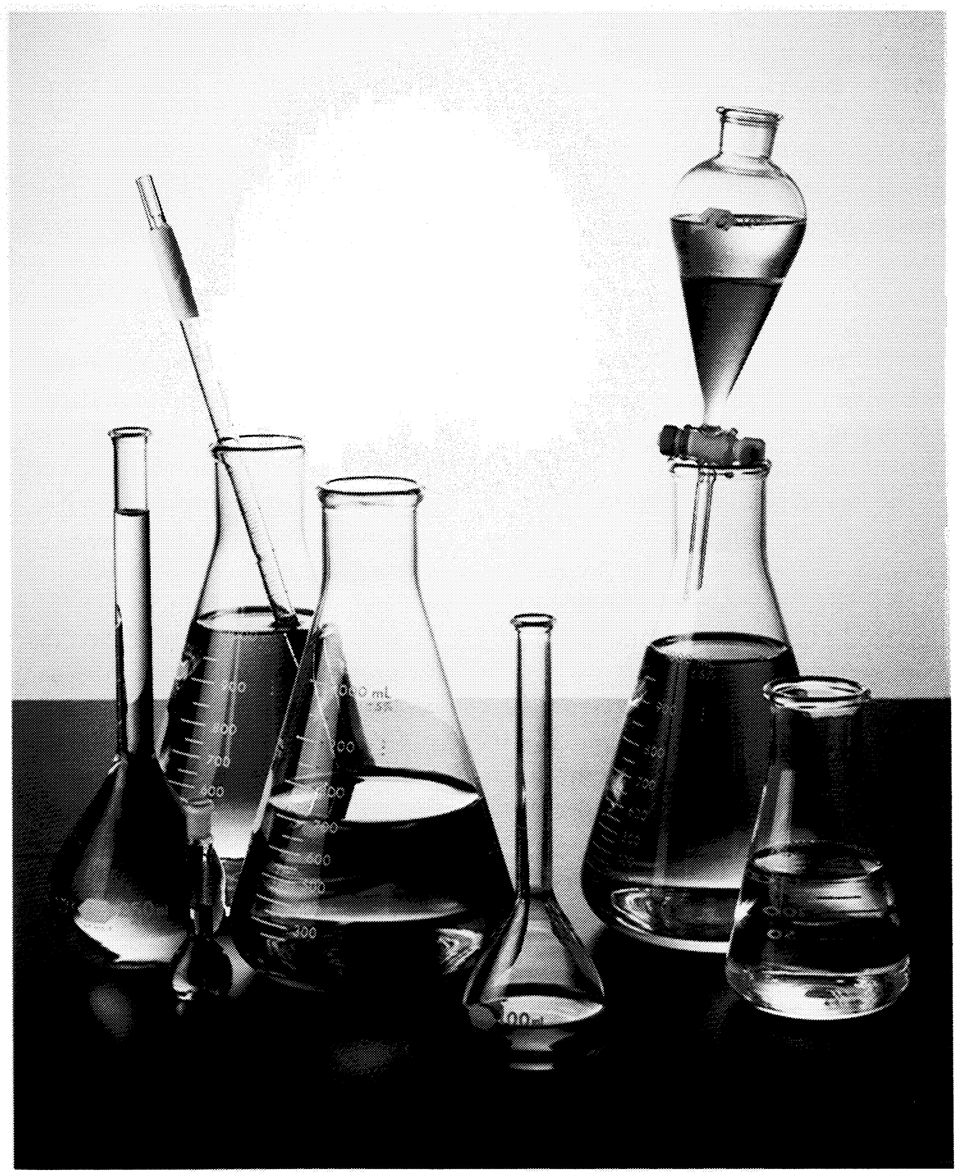
An Air Force van (above) is being used at Langley Air Force Base, Virginia as a service test vehicle for a new type of automotive propulsion system with broad promise, the Stirling external combustion engine (right). The Stirling engine is a European technology being developed for American use in a NASA/Department of Energy program.



An advanced technology Stirling engine offers multiple advantages, principal among them reduced fuel consumption and lower exhaust emissions than comparable internal combustion auto engines, plus multifuel capability. This photo illustrates the wide variety of fuels the Stirling can use: gasoline, kerosene, diesel fuel, jet fuel, alcohol, methanol and butane—and that's not the whole list.

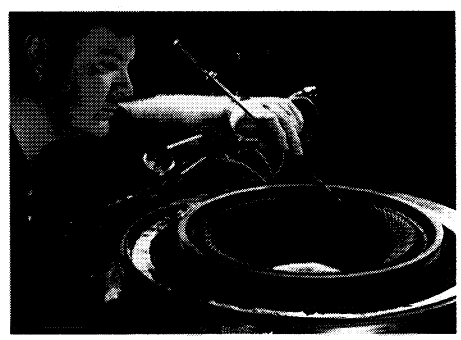
U.S. interest in the Stirling external combustion engine concept began in the mid-1970s, when the Environmental Protection Agency was looking for an alternative automotive engine with significantly lower exhaust emissions than other engines of that vintage, and additionally was seeking improved automotive fuel economy as a national energy conservation measure, along with multifuel capability to reduce reliance on fossil fuels.

To those national objectives, NASA added another when Lewis Research Center took over management of the Stirling engine project in 1978; minimization of the strategic element content of the engine's metal alloys, to reduce demand for scarce strategic materials. Lewis and its contractor—Mechanical Technology, Inc. (MTI)—have developed low cost substitute metal alloys that eliminated cobalt and significantly reduced the chromium content.

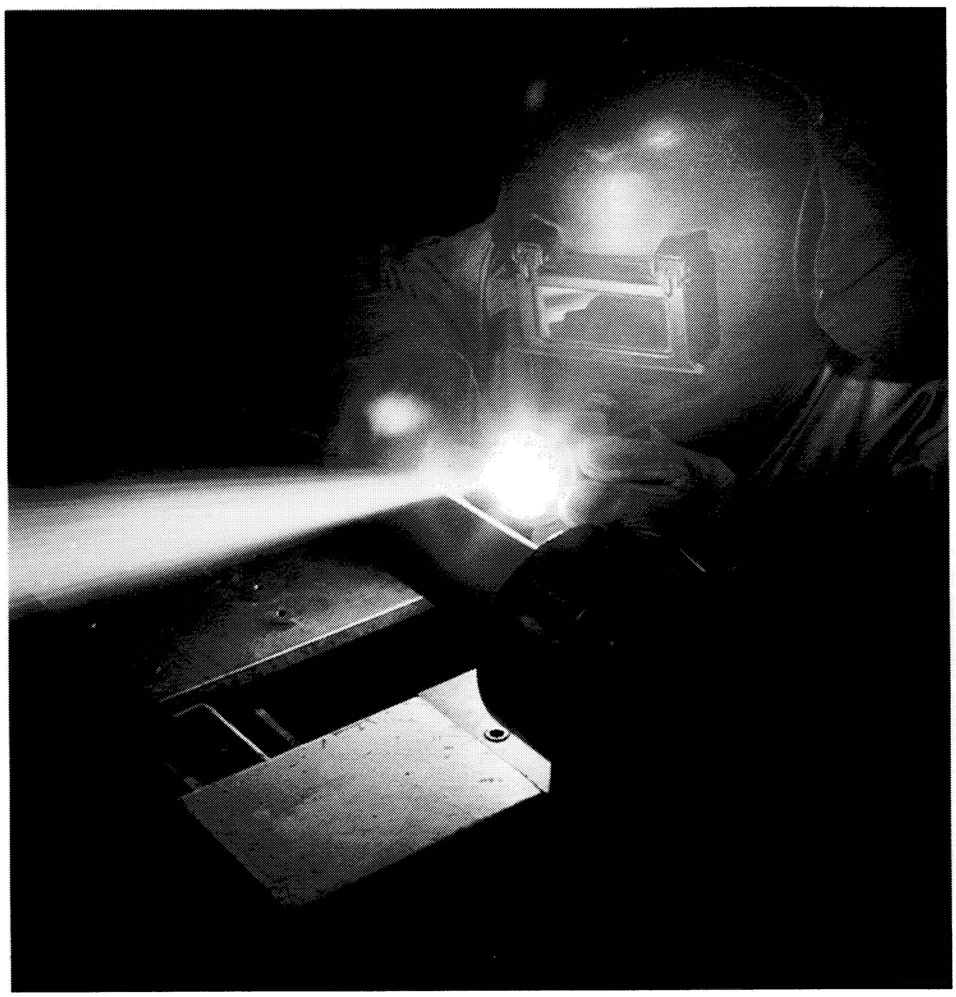
The first stage of the Automotive Stirling Engine program was the 1984 Industry Test and Evaluation Program, an independent evaluation of the Stirling Mod I engine by an auto manufacturer and an engine builder—General Motors Research Laboratories (GMRL) and Deere & Company. The engine was installed in a 1981 Spirit auto and conducted emission, mileage, cooling and driver evaluations. Deere ran the engine for 37 hours in a test cell on gasoline, diesel and jet fuel under a variety of operating conditions. GMRL reported that the engine met federal emission standards with a "comfortable margin," despite the fact that the engine was operated without a catalytic converter. Both companies experienced no major hardware failures and test results were generally favorable.

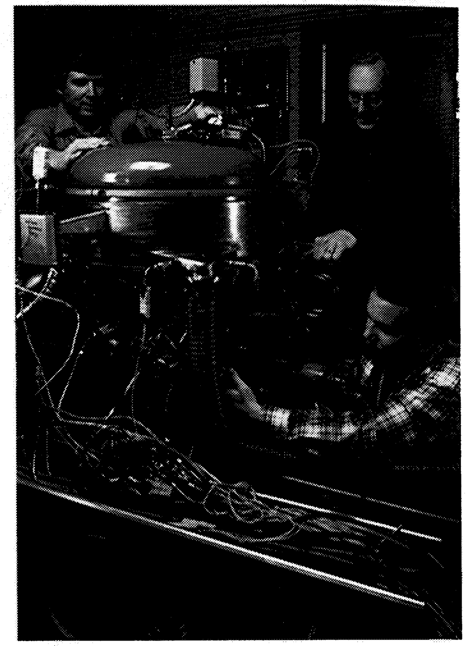
A follow-on evaluation—called the Government and Industry Participation Program (GIPP)—was initiated in 1985. One GIPP activity under way is an investigation of the Stirling's potential as an electricity generator. The Army's Fort Belvoir (Virginia) has tested a standard Army engine-generator set in which a Stirling Mod 1 is taking the place of the regular diesel engine.

The primary GIPP activity is the Stirling-powered Air Force van project. This is a three-phase program in which Phase I covers routine service testing of a four-cylinder,



The configuration of the Mod II Stirling automotive engine is shown clearly in the upper photo, an uncluttered, wood-sculpted model built for checking precise dimensions prior to machine tooling of parts. The inverted dishpan at top (colored blue) houses the engine's external heat system, including the heater head where combustion takes place. In the lower photo is a closeup of the heater head with its cover removed.



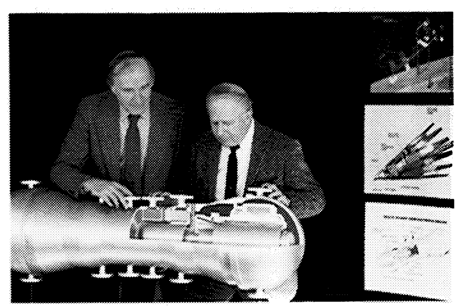


Engineers and technicians of the Stirling Automotive Engine project hook up an engine to a dynamometer prior to a test cell run at various speeds and loads; the extensive wiring is for data recording, not part of the engine.

Lewis Research Center invented a special high-temperature lubricant coating for the Stirling engine; here a Lewis technician is flame-spraying it onto parts of an experimental engine.

78-horsepower Mod 1 engine—400 hours operating on unleaded gasoline and 400 more on kerosene-based jet fuel—in the moderate climate of Langley Air Force Base, located in southern Virginia. By mid-1987, Phase I was nearing completion, after which the engine was to undergo additional testing with diesel fuel.

If Phase I proves successful, Phase II will involve further in-service evaluations of van-mounted engines operating at a higher temperature—820 degrees Centigrade, compared with Phase I's 720 degrees—under a variety of climates and user conditions. Plans for Phase III have yet to be detailed, but generally it will consist of extensive testing of a lighter yet more powerful (85 horsepower) Mod II engine incorporating many of the advanced technologies developed in the course of the program. The projected fuel economy for the Mod II engine, installed in a mid-size car, is 63 miles per gallon on the highway and 33 miles per gallon in city traffic, for an overall average of 42 miles per gallon—approximately 30 percent better than the fuel consumption of a comparable conventional engine. ▲



The Stirling engine has a number of potentially advantageous applications other than automotive use, among them irrigation pumping, heat pumps, and electricity generation for submarine, Earth and space systems. Here project engineers are examining a model of a Stirling "free piston" variant that could be used in the NASA/international Space Station to generate 25 kilowatts of electricity.